DISTAL RADIUS AND PROXIMAL FEMUR FRACTURE PATTERNS IN THE HAMANN-TODD SKELETAL COLLECTION

ROBERT P. MENSFORTH

Department of Anthropology
University of Oklahoma
Norman, Oklahoma 73019

and

SUSAN A. SUROVEC
JAMES R. CUNKLE

Department of Anthropology
Cleveland State University
Cleveland, Ohio 44115

Abstract

The study presents a retrospective analysis of distal radius and proximal femur fractures that occurred in 938 Hamann-Todd Collection skeletons. Individuals included in the investigation were retrieved from dissecting room cadavers in Cleveland, Ohio, between the years 1910 and 1938. Demographic analysis showed that mean age at death was 41.9 years for Blacks and 53.8 years for Whites examined in the study. Observations of remodeling status and side of involvement were recorded for all fractures identified. It was found that the age, sex, and race specific fracture patterns, which characterize the early twentieth-century Hamann-Todd sample, strongly correspond to those seen in modern American and European communities. The most striking difference between Hamann-Todd fracture patterns and those seen in modern groups concerns that much greater total frequency of traumatic injuries that occurred in the former group. Although hip fractures appear to be a primary result of age progressive skeletal fragility, it is suggested that the early onset, and high incidence, of distal radius fractures that occur in climacteric Caucasian women may be more directly due to accidents initiated by a greater frequency, intensity, and duration of vasomotor disturbances, which are known to accompany estrogen withdrawal in perimenopausal White females.

Introduction

Over the past several decades American and European populations have experienced a demographic shift whereby increasing numbers of people survive to old age (Gordon 1984; Johnell et al. 1984). Although continuing advances in medical technology and improvements in health care delivery systems are primarily responsible for such trends, we also have witnessed changes in the major causes of morbidity and mortality in these groups (Kilbourne and Smillie 1969). Thus, it is not surprising to find that contemporary sociological, epidemiological, and elinical researchers have been devoting greater attention to the health care problems of the aged.

One of the major problems that characterizes the geriatric segment of our society is a high incidence of traumatic injuries. For example, Gordon (1984) reports that 225,000 hip fractures occur annually in the United States. Over two-thirds of these occur in elderly women. The financial costs associated with hip fractures in the United States now approximates 3.8 billion dollars a year. However, old-age fractures are costly not only in terms of clinical management, but also in constituting a major risk of mortality. Compared to younger individuals, it is well recognized that old people who have fractures are much more vulnerable to complications as a result of surgery and/or immobilization (Robbins 1974). These include thromboembolism, pneumonia, and death. Thus, it is not remarkable that hip fractures are now the 12th leading cause of death among the elderly in the United States (Gordon 1984).

These problems motivated Buhr and Cooke (1959) to conduct one of the first comprehensive surveys of fracture epidemiology in a modern urban industrial community. They examined fractures in individuals from England and Wales whose ages ranged from birth to 80+ years. It was found that traumatic injuries were characterized by marked age and sex specific patterns, which could be classified as one of four types (Buhr and Cooke 1959). These are L-Type, J-Type, A-Type, and Composite fracture patterns.

For example, an L-Type fracture pattern (e.g., supracondylar fractures of the distal humerus; Fig. 1, upper left) typically shows a peak incidence at an early age, followed by a subsequent decrease in frequency to levels that are relatively insignificant. In contrast, the J-Type pattern identifies old-age fractures (Fig. 1, upper right). Here, the frequency of traumatic injury is low throughout childhood, and early and middle adulthood. Beyond 60 years of age J-Type fractures (e.g., hip fractures) show an

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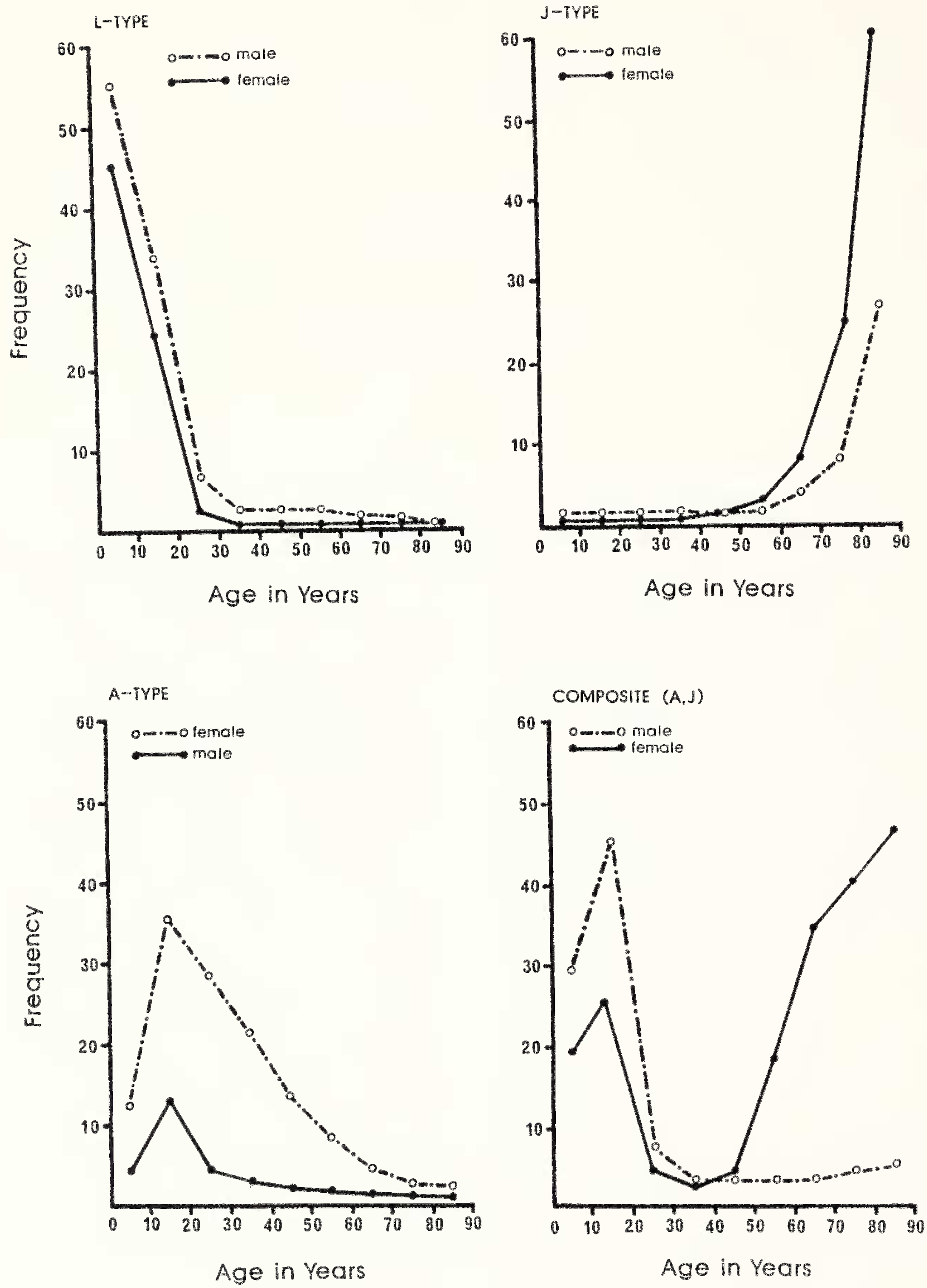


Fig. 1. Typical age and sex specific fracture patterns observed in modern human groups. Fracture frequencies are variably reported as number of cases per million, annual incidence per 10,000, incidence per 10,000 per age class, or percent of individuals affected per age class. The patterns shown here were adapted from Buhr and Cooke (1959).

age progressive increase, and usually reach peak incidence in the oldest decade of life. The A-Type fracture pattern (e.g., phalangeal fractures; Fig. 1, lower left) describes those traumatic injuries that have a low initial frequency, then rise to reach peak incidence, and subsequently decline to a low frequency once again. Finally, a Composite fracture pattern (e.g., distal radius fractures; Fig. 1, lower right) refers to those traumatic injuries that display two, or more, of the age related patterns described thus far. The different types of fracture patterns observed may also be characterized by sex differences in age at onset and peak frequency of occurrence.

The two J-Type traumatic injuries of old age that have been examined most thoroughly in contemporary epidemiological studies are distal radius and proximal femur fractures. The former primarily are represented by fractures of the Colles, Smith, and Barton types (Bacorn and Kurtzke 1953; Older et al. 1965; Koefed 1983). Proximal femur fractures include compression fractures of the femoral head, subcapitular and basilar fractures of the femoral neck, and intertrochanteric fractures (Buhr and Cooke 1959; Bauer 1960; Alffram and Bauer 1962; Knowelden et al. 1964; Little 1973; Freeman et al. 1974; Johnell et al. 1984; Bengner and Johnell 1985; Solgaard and Petersen 1985).

The age and sex specific patterns that characterize distal radius and proximal femur fractures are illustrated in Fig. 2. The shown fracture patterns represent traumatic injuries that occurred in White males and females from England and Wales (Buhr and Cooks 1959), and

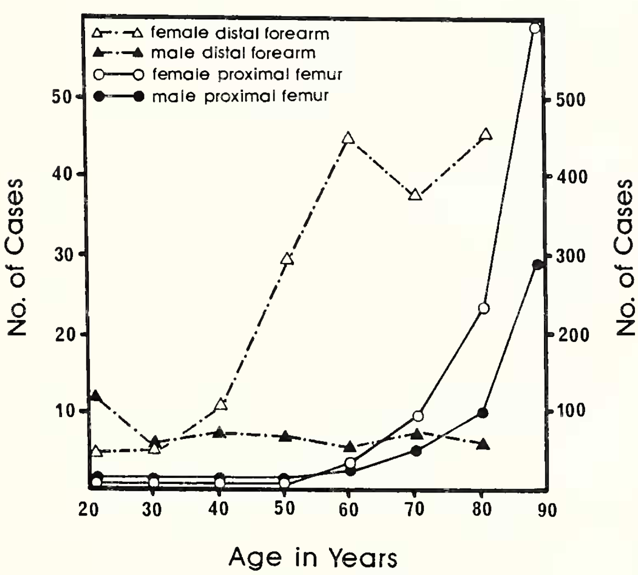


Fig. 2. Incidence of distal forearm and proximal femur fractures in a contemporary population from England and Wales. Annual fracture rates are represented as number of cases per million. The left vertical margin shows the frequency of distal forearm fractures. The right vertical margin shows the frequency of proximal femur fractures. Adapted from Buhr and Cooke (1959).

they are by no means unique. Although annual incidence per 10,000 may vary from one geographic region to another, identical patterns for these two types of traumatic injury have been observed repeatedly (Bauer 1960; Johnell et al. 1984; Gordon 1984; Solgaard and Petersen 1985).

The fundamental age and sex related differences, which discriminate between distal radius and proximal femur fracture patterns, can be described as follows. Distal radius fractures in females show an early age at onset where a high incidence is established in the menopausal years. Thereafter, distal radius fractures in females attain what might be described as a plateau phase where a high frequency is maintained, but does not appear to increase. In contrast, males over 30 years of age have a low frequency of distal radius fractures throughout life and do not exhibit an old age J-Type pattern (Buhr and Cooks 1959; Bauer 1960).

Proximal femur fracture rates illustrated in Fig. 2 show that these traumatic injuries are uncommon in males and females under 60 years of age. Thereafter, both sexes exhibit a typical J-Type age progressive increase in the frequency of hip fractures. However, females display fracture rates that are at least two times greater than those of males. Moreover, accelerated fracture rates in males begin to rise approximately ten years later than in females.

With regard to etiology, a number of exogenous and endogenous factors are known to promote fracture risk in modern industrial communities (Buhr and Cooke 1959; Alffram and Bauer 1962). The former represent a group of nonbiological environmental circumstances, such as occupational hazards and automobile accidents. Geographic location and seasonality also have been implicated in differential fracture incidence in human groups (Gordon 1984; Solgaard and Petersen 1985; Bengner and Johnell 1985).

However, among old people it is well recognized that endogenous factors play a dominant role in elevated risk, and increased severity, of traumatic injury (Bauer 1960). These include disease conditions that often result in pathological fractures (e.g., bone cysts, bone cancers, Paget's disease, etc.) and degenerative consequences of biological aging (Buhr and Cooke 1959). The latter are far more important in fracture risk and include degenerative sequelae, such as failing eyesight, impaired motor coordination, muscular weakness and atrophy, and pronounced bone loss with age. Thus, as biological age progresses in men and women, the frequency of accidental injuries continues to rise (Alffram and Bauer, 1962; Knowelden et al 1964).

Indeed, Solgaard and Petersen (1985) report that the majority of distal radius fractures that occur in women (87%) and men (64 %) are the result of falls from level ground. Studies also have shown that hip fractures in individuals over 70 years of age are most often due to falls.

or movements we would ordinarily regard as trivial (e.g., arising from a seated position; Jaffe 1972; Johnell 1984). Thus, a greater frequency of relatively minor accidents in old people results in a greater incidence of moderate to severe traumatic injuries.

A significant body of clinical and epidemiological research has established a strong positive association between age and sex specific fracture patterns and bone loss with age. The results of such studies are summarized elsewhere, and they will not be reviewed in detail here (see Alffram and Bauer 1962; Chalmers 1973; Goldsmith et al. 1973; Wasnich et al. 1985; and references therein). It will suffice to state that a slow normal rate of bone loss begins in males and females during the 4th decade of life (Goldsmith et al. 1973). However, during the menopausal years women experience an accelerated rate of bone loss due to the cessation of ovarian function and estrogen withdrawal (Meema and Meema 1976; Horsman et al. 1977). Therefore, by age 60 adult females often show a significant reduction in skeletal mass, marked osteoporosis, and subsequently display an earlier onset age for J-Type fractures compared to males (Chalmers and Weaver 1966; Chalmers 1973).

Racial differences in skeletal metabolism have also been demonstrated. Studies show that Black men and women attain higher peak bone mineral density values compared to Whites (Trotter et al. 1960; Goldsmith et al. 1973). Although Blacks lose bone at rates that are comparable to Whites, they enter the older decades of life with a relatively, and absolutely, greater bone mineral content (Goldsmith et al. 1973). Thus, it is not remarkable to find that the incidence of osteoporosis, and old-age fractures, is significantly lower in older Black men and women compared to Whites, and other racial groups as well (Gordon 1984).

Given the epidemiological relationships described thus far, the purpose of the present investigation is to examine the frequency with which distal radius and proximal femur fractures occurred in a sample of skeletons that were assembled in Cleveland, Ohio, during the earlier part of the twentieth century. The study is therefore retrospective and replicative in nature. Here, it is specifically hypothesized that:

(1) White females will display a greater frequency of distal radius fractures compared to all other sex/race subgroups,
(2) age at onset for increased incidence of distal radius fractures in White females will occur during the perimenopausal and menopausal years (i.e., the period between 40 and 60 years),
(3) White females will display a greater frequency of hip fractures compared to all other sex/race subgroups,
(4) age at onset for increased incidence of hip fractures in White females will be 60 years of age,
(5) age at onset for increased incidence of hip fractures in White males will be 70 years of age, or approximately 10 years later than in females,
(6) a low frequency of hip fractures should characterize all sex/race subgroups under 60 years of age,
(7) Black males and females will show a lower frequency of distal radius and proximal femur fractures at all ages compared to Whites,
(8) Black males and females will show no significant increase in the frequency of distal radius and proximal femur fractures with age, and
(9) Black males will show the lowest frequency of distal radius and proximal femur fractures compared to all other sex/race subgroups.

Although age at death, sex, and race are known for the individuals used in this study, a potential problem concerns the fact that adequate medical histories are unavailable for the skeletons examined. This means that the age at which fractures occurred is only known for those traumatic injuries appearing unremodeled at time of death. Therefore, the fracture frequency data to be discussed are best regarded as cumulative in nature. Nonetheless, sex and race differences in age at onset for increased incidence of distal radius and proximal femur fractures should remain unaffected and easy to detect. Therefore, the J-Type fracture patterns that occurred in an early twentieth-century urban industrial American community were investigated in the following manner.

Materials

The human skeletal remains employed in this study are from the Hamann-Todd Collection. The bulk of this historic collection was assembled between the years 1910 and 1938, by Western Reserve University anatomists. Under the direction of T. Wingate Todd, the skeletons of over 3,400 dissecting room cadavers were retrieved for future scientific research. These skeletal materials are now permanently curated by the Cleveland Museum of Natural History. It is important to realize that many of the individuals included in the Hamann-Todd Collection were transients, indigents, and persons of low socioeconomic status. Thus, the sample used in this study is best regarded as a biased cross section of early twentieth-century urban industrial America.

At present, the Hamann-Todd Collection contains records that document age and sex for the skeletal remains of 3,157 Black and White Americans. These specimens are partitioned by sex and race in Table 1. It can be seen that sex ratios are markedly skewed in favor of males. The male:female sex ratios for Blacks and

TABLE 1
Black and White Adults in the
Hamann-Todd Cadaver Records

Race	*Male* n_1	*Female* n_2	*Sex Ratio*
Blacks	901	279	3.23
Whites	1725	252	6.85
Total[a]	2626	531	4.95[b]

[a]Among the 3,157 Hamann-Todd Black and White adults (+18 years) listed in cadaver records, a total of 1,180 (37.4%) Blacks and a total of 1,977 (62.6%) Whites are represented.
[b]For both races combined males outnumber females by a factor of five.

Whites are 3.23 and 6.85, respectively. In addition, 88 adults and an unspecified number of subadults that are listed in cadaver records were returned to relatives for burial, or were cremated, following autopsy. Given these circumstances, the following sampling strategy was employed.

At the time of observation a total of 262 Black and 207 White females were available for study. An equivalent number of Black and White males were then age-matched to their respective female samples. This was done to establish balanced adult age distributions and sex ratios. Thus, a total of 938 adult skeletons (Black n = 524; White n= 414) were examined for distal radius and proximal femur fractures.

Methods

All Hamann-Todd specimens included in the study were macroscopically examined for the presence/absence of distal radius and proximal femur fractures. Distal radius fractures are defined as those fractures that occurred within 4 cm. of the distal articular surface of the radius. Proximal femur fractures were divided into two classes. The first is intracapsular fractures of the proximal femur (PIC), and the second is extracapsular fractures of the proximal femur (PEC). The former are represented by compression fractures of the femoral head and subcapitular fractures of the femoral neck. The latter include basilar fractures of the femoral neck and intertrochanteric fractures of the proximal femur. No fractures that were situated below the intertrochanteric line were included in the study.

Four skeletal sites were examined for each specimen. These were the left and right proximal femora and distal radii, respectively. Adult males who were missing one or more of the sampling sites were replaced by complete age-matched specimens. Only three adult females were missing one observation per individual (i.e., .08% of all observations). For these females the missing skeletal site was assumed not to have been fractured.

The identified fractures were then scored with respect to symmetry. Unilateral left, unilateral right, and bilateral involvements were recorded. Fractures were also qualitatively assessed as remodeled, or unremodeled, at time of death. This was done in order to estimate the risk of mortality associated with each fracture type.

All fractures that were identified in our initial survey were then re-examined on a second occasion. This procedure ensured that bony changes due to degenerative joint disease, and other pathological conditions, would not mistakenly be diagnosed as traumatic injuries (i.e., pathological fractures were not included in the analysis). Likewise, all bones that showed evidence of post-mortem damage were carefully gleaned so that all fracture 'mimics' were excluded from consideration. Thus, the fracture data to be summarized in the study are reported with a high degree of confidence.

The investigation results are presented in graphic and tabular form. Where appropriate, nonparametric probability statistics were used to evaluate differences in fracture symmetry, remodeling status, and age, sex, and race differences in the fracture patterns observed.

Results

Demographic Composition of the Hamann-Todd Samples

The age distributions for Blacks and Whites examined in the study are listed by five-year age intervals in Table 2. For comparison, more recent aggregate census data for the United States in 1960, is given in Table 3 (Thomlinson 1965). Survivorship curves for these data are illustrated in Fig. 3. It can be seen that the Hamann-Todd Black and White age distributions differ markedly from the modern age profile. The greater survivorship, which characterizes

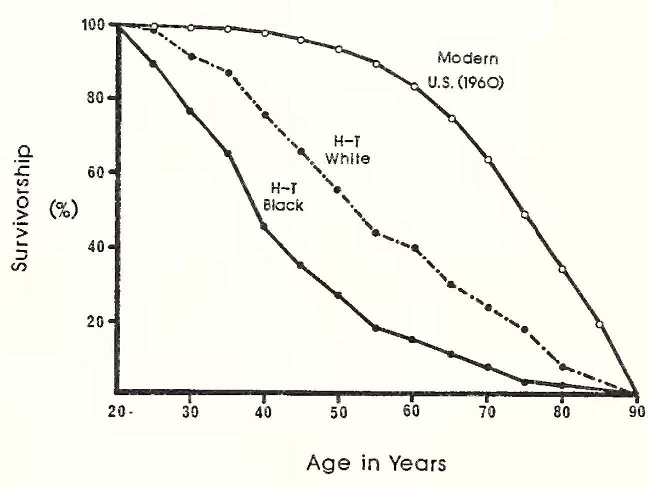


Fig. 3. Survivorship curves for the Hamann-Todd Black and White samples, compared to survivorship reported for more recent aggregate census data for the United States in 1960 (see Thomlinson 1965).

TABLE 2
Age Distributions for the Black and White Male and Female Adult Samples Used in the Fracture Study

Age	White Sample n_1	White Sample %	l_x	Black Sample n_2	Black Sample %	l_x
18–24	5	2.4	100.0	30	11.5	100.0
25–29	14	6.8	97.6	34	13.0	88.5
30–34	10	4.8	90.8	29	11.1	75.5
35–39	24	11.6	86.0	50	19.1	64.4
40–44	19	9.2	74.4	29	11.1	45.3
45–49	22	10.6	65.2	21	8.0	34.2
50–54	24	11.6	54.6	23	8.8	26.2
55–59	9	4.3	43.0	8	3.1	17.4
60–64	19	9.2	38.7	10	3.8	14.3
65–69	13	6.3	29.5	10	3.8	10.5
70–74	13	6.3	23.2	10	3.8	6.7
75–79	20	9.7	16.9	2	0.8	2.9
+80	15	7.2	7.2	6	2.3	2.1
Total[a]	207[b]			262[c]		

[a]The total number of Hamann-Todd specimens included in the study equals 938.
[b]The 207 adult white females available for analysis were age-matched with 207 adult white males. The sample of adult whites examined thus equals 414 individuals.
[c]The 262 adult black females available for analysis were age-matched with 262 adult black males. The sample of adult blacks examined thus equals 524 individuals.

TABLE 3
Age Distribution for Modern Adults

Age[a]	N	%	l_x
20	558	0.58	100.0
25	611	0.64	99.4
30	732	0.76	98.8
35	1124	1.17	98.0
40	1719	1.79	96.9
45	2595	2.70	95.1
50	3987	4.15	92.4
55	5616	5.84	88.2
60	7911	8.23	82.4
65	11132	11.58	74.1
70	13851	14.40	62.6
75	14173	14.74	48.2
80	14383	14.96	33.4
+85	17767	18.48	18.5
Total	96159		

[a]These are aggregate United States census data for 1960 as reported in Thomlinson 1965.

the latter group, is undeniably a consequence of technological advances in medicine and improvements in health care delivery systems that have occurred over the past 60 years.

Marked differences also characterize the Hamann-Todd Black and White age distributions. Mean ages for the Black and White samples used in the study are 41.9 and 53.8 years, respectively. A Kolmogorov-Smirnov test indicates that the two age distributions are significantly different ($x^2 = 38.90$; $p<.001$). The lower mean age at death among Blacks may reflect socioeconomic and racial factors that compromised access to health care during the late nineteenth and early twentieth centuries. Here, the circumstance that only a small proportion of the Blacks sampled are over 60 years of age is thus regarded as a potential source of error in our attempt to accurately estimate the incidence of old age fractures in this group.

General Observations

Several of the distal radius and proximal femur fractures, which were identified in the Hamann-Todd series, are illustrated in Fig. 4. In general, degree of severity varied widely for the distal radius fractures that were observed. Traumatic involvement ranged from relatively benign hairline fractures of the subchondral bony joint surfaces, to those where severe trauma resulted in marked displacements and angular distortion of the distal radius. Proximal femur fractures were much more obvious. Intracapsular fractures of the proximal femur (PIC) typically displayed a marked shortening of functional femur neck length, combined with distortion of normal spherical contours of the femoral head. Extracapsular proximal femur fractures (PEC) were frequently situated at the base of the femoral neck, and they were often accompanied by the bony fragments of associated intertrochanteric fractures.

Among the 938 skeletons that were examined, a total of 77 (8.2%) individuals displayed one or more distal radius fracture. Only 34 (3.6%) specimens exhibited proximal femur fractures. Thus, distal radius fractures were 2.3 times more frequent than hip fractures. A chi square comparison indicates that this difference is highly significant ($x^2 = 17.71$; $p<.001$). For proximal femur fractures alone, a total of 22 (2.4%) individuals had extracapsular hip fractures, while only 12 (1.3%) specimens displayed intracapsular hip trauma. The difference in frequency for these two classes of hip fracture is not significant ($x^2 = 3.00$; $p>.05$). All fractured individuals are partitioned by sex and race in Appendix A. Information summarized there identifies each specimen's catalogue number, age at death, as well as the specific type, symmetry, and remodeling status for those fractures that were observed (Appendix A Table 21).

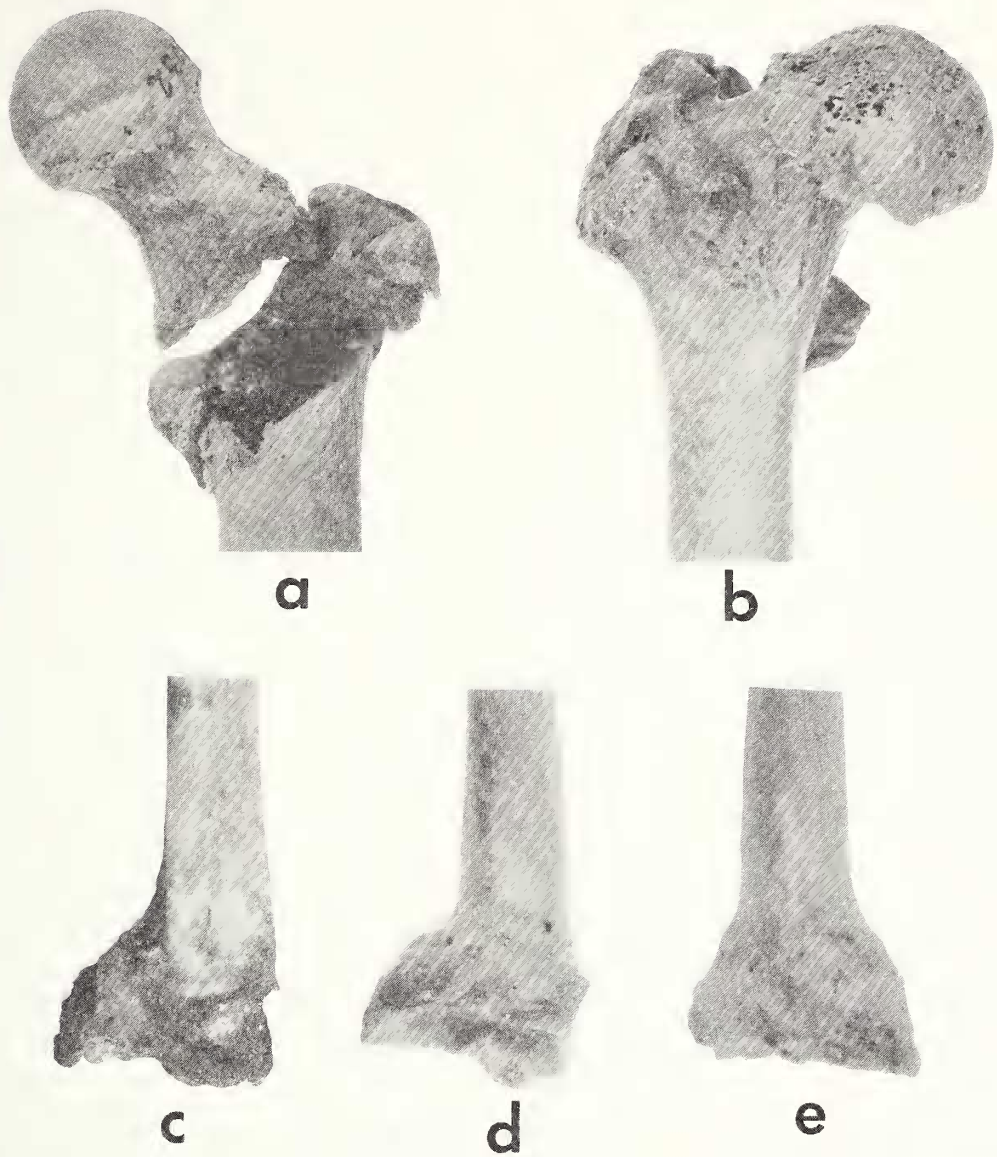


Fig. 4. Examples of proximal femur and distal radius fractures which were observed in the Hamann-Todd Collection. *A*, left proximal femur which manifests a basilar neck fraeture combined with an intertrochanteric fracture (CMNH-HT-3032, 89-year-old White female); *B*, Subcapital fracture of the right femoral neck which subsequently led to ischemic necrosis of the femoral head (CMNH-HT-1024, 84-year-old White female); *C*, anterior view of a Colle's fracture affeeting the right distal radius (CMNH-HT-1402, 81-year-old White female); *D*, posterior view of Colle's fracture affecting the left radius; and *E* posterior view of Colle's fracture affecting the right radius of the same individual (CMNH-HT-1581, 83-year-old White female).

Fracture Symmetry

The frequency with which distal radius and proximal femur fractures were seen on the left, right, or both sides of affected individuals is summarized in Table 4. These data are partitioned by sex and race in Appendix B (Table 22). In general, 8-9% of all fractures were seen to occur bilaterally. Nonetheless, it was not possible to determine if bilateral involvements were the result of the same traumatic episode. For several individuals this did not seem to be probable. Patterns for unilateral involvement indicate no side preference for distal radius or proximal femur fractures. A chi square comparison confirms that no significant difference in unilateral expression characterizes the fractures which were identified in the study ($x^2 = 0.02$; $p > .80$).

TABLE 4
Distal Radius and
Proximal Femur Fracture Symmetry

Fracture Type	*Total No. of Individuals with Fractures*	*Left* n_1	%	*Right* n_2	%	*Bilateral* n_3	%
Distal Radius	77	36	46.8	32	41.6	7	9.1
Proximal Femur	34	16	47.1	15	44.1	3	8.8

Fracture Remodeling Status

The frequencies with which distal radius and proximal femur fractures appeared remodeled, or unremodeled, at time of death is given in Table 5. These data are partitioned by sex and race in Appendix C (Table 23). It was found that 88% of distal radius fractures, and 87% of intracapsular hip fractures, were healed at time of death. Though varying degrees of functional immobility undoubtedly accompanied many of these injuries, it is concluded that distal radius and intracapsular proximal femur fractures were well tolerated from a clinical perspective.

TABLE 5
Distal Radius and Proximal Femur
Fracture Remodeling Status

Fracture Type	*Total No. of Fractures Observed*	*Remodeled* n_1	%	*Unremodeled* n_2	%
Distal Radius	84	74	88.1	10	11.9
Femur (PIC)	15	13	86.7	2	13.3
Femur (PEC)	22	5	22.7	17	77.3

In contrast, only 23% of extracapsular hip fractures were remodeled at time of death. Chi square values listed in Table 6 show that the marked remodeling differential between extracapsular hip fractures, and those described above, is statistically signifieant. It is concluded that individuals who acquired extracapsular fractures of the proximal femur had a very high risk of mortality. That is, approximately eight out of every ten Hamann-Todd specimens with femur neck fractures probably died as a direct, or indirect, consequence of the traumatic injury.

TABLE 6
Chi Square Values for Comparisons of Distal Radius and
Proximal Femur Fracture Remodeling Status

Comparison	*Chi Square*
Distal Radius vs. Femur (PEC)	39.24[a]
Distal Radius vs. Femur (PIC)	0.26
Femur (PIC) vs Femur (PEC)	13.14[a]

[a]Significant at .001 level of probability.

Old Age Fracture Patterns in the Hamann-Todd Collection

The frequency with which distal radius and proximal femur fractures were observed for Hamann-Todd Black and White males and females is given by decade in Tables 7, 8, 9, and 10. These data are listed by five-year age intervals in Appendix D; Tables 24, 25, 26, and 27. The Black and White age and sex specific fracture patterns are illustrated in Figure 5. The total frequency with which fractures occurred is partitioned by sex and race for each fracture type in Table 11. Data summarized there are expressed as the total number of individuals affected.

Results show that White females experienced a greater frequency of distal radius and proximal femur fractures compared to all other sex/race subgroups. In descending frequency, the rank order for distal radius fractures is White female (19.3%), White male (7.2%), Black female (6.5%), and Black male (1.9%). The rank order for proximal femur fractures is White female (9.7%), White male (3.4%), Black male (1.5%), and Blaek female (1.2%). Chi square values (Table 12) indicate that both Black and White women had a significantly greater frequency of distal radius fractures compared to those of the proximal femur. Similar comparisons for Black and White men were insignificant.

TABLE 7
Age Specific Fracture Frequencies for White Females Listed by Decade

Age	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–29	19	0	0.0	0	0.0	0	0.0	0	0.0
30–39	34	1	2.9	0	0.0	0	0.0	0	0.0
40–49	41	6	14.6	0	0.0	1	2.4	1	2.4
50–59	33	10	30.0	1	3.0	1	3.0	2	6.1
60–69	32	6	18.8	0	0.0	5	15.6	5	15.6
70–79	33	9	27.3	0	0.0	4	12.1	4	12.1
+80	15	8	53.3	3	20.0	5	33.3	8	53.3
Total	207	40	19.3	4	1.9	16	7.7	20	9.7

TABLE 8
Age Specific Fracture Frequencies for White Males Listed by Decade

Age	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–29	19	0	0.0	0	0.0	0	0.0	0	0.0
30–39	34	3	8.8	0	0.0	0	0.0	0	0.0
40–49	41	1	2.4	0	0.0	0	0.0	0	0.0
50–59	33	1	3.0	0	0.0	0	0.0	0	0.0
60–69	32	3	9.4	1	3.1	1	3.1	2	6.3
70–79	33	5	15.2	0	0.0	1	3.0	1	3.0
+80	15	2	13.3	1	6.7	3	20.0	4	26.7
Total	207	15	7.2	2	1.0	5	2.4	7	3.4

TABLE 9
Age Specific Fracture Frequencies for Black Females Listed by Decade

Age	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–29	64	0	0.0	0	0.0	0	0.0	0	0.0
30–39	79	4	5.1	0	0.0	0	0.0	0	0.0
40–49	50	4	8.0	0	0.0	0	0.0	0	0.0
50–59	31	2	6.5	0	0.0	0	0.0	0	0.0
60–69	20	6	30.0	1	5.0	1	5.0	2	10.0
70–79	12	0	8.3	1	8.3	0	0.0	1	8.3
+80	6	1	16.7	0	0.0	0	0.0	0	0.0
Total	262	17	6.5	2	0.8	1	0.4	3	1.1

TABLE 10
Age Specific Fracture Frequencies for Black Males Listed by Decade

Age	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–29	64	1	1.6	1	1.6	0	0.0	1	1.6
30–39	79	0	0.0	1	1.3	0	0.0	1	1.3
40–49	50	1	2.0	1	2.0	0	0.0	1	2.0
50–59	31	1	3.2	0	0.0	0	0.0	0	0.0
60–69	20	2	10.0	1	5.0	0	0.0	1	5.0
70–79	12	0	0.0	0	0.0	0	0.0	0	0.0
+80	6	0	0.0	0	0.0	0	0.0	0	0.0
Total	262	5	1.9	4	1.5	0	0.0	4	1.5

TABLE 11
Summary of Number and Frequency of Fractures Observed in the Hamann-Todd Sample

Fracture Type	White Female (N=207) n	%	White Male (N=207) n	%	Black Female (N=262) n	%	Black Male (N=262) n	%
Distal Radius	40	19.3	15	7.2	17	6.5	5	1.9
Femur (PIC)	4	1.9	2	1.0	2	0.8	4	1.5
Femur (PEC)	16	7.7	5	2.4	1	0.4	0	0.0
Total Proximal Femur[a]	20	9.7	7	3.4	3	1.2	4	1.5
Total	53[b]	25.6	22	10.6	20	7.6	9	3.4

[a]Figures listed for total proximal femur are simply the summed observations for the catergories of femoral (PIC) and femoral (PEC) fractures.
[b]A total of 7 adult White female individuals displayed combined fractures of the distal radius and proximal femur at time of death. Thus a total of 53 White females (60-7) had one or more old-age fractures at time of death. No White males and no Blacks displayed combined distal radius and proximal femur fractures at time of death.

TABLE 12
Chi Square Values Comparing the Difference in Total Frequency for Distal Radius versus Proximal Femur Fractures

	Distal Radius vs. Proximal Femur
White Female	7.80[a]
White Male	3.07
Black Female	9.25[a]
Black Male	0.11

[a]Significant at the .01 level of probability.

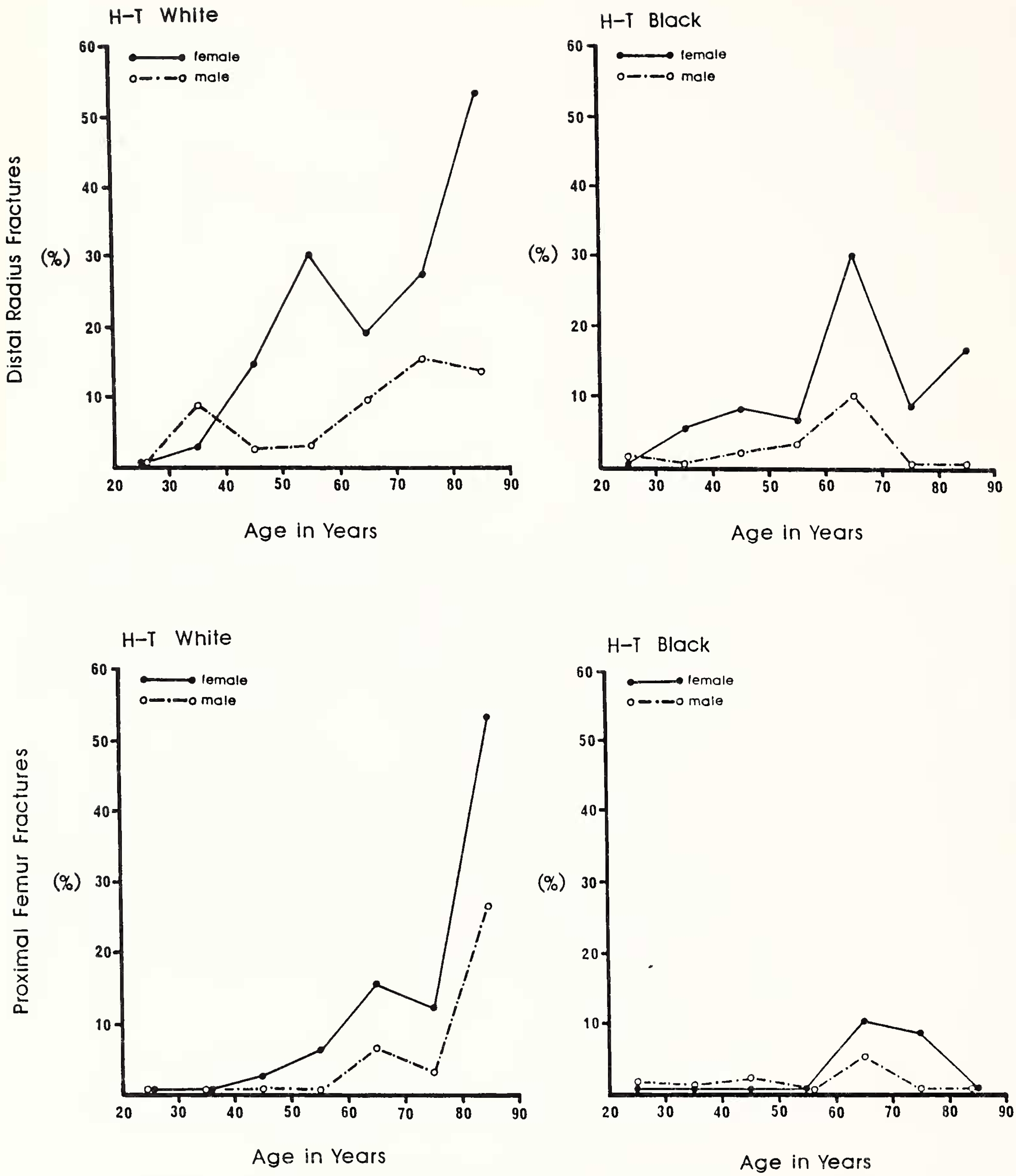


Fig. 5. Age, sex, and race specific frequency of distal radius and proximal femur fractures that were observed in the Hamann-Todd sample.

Chi square values given in Table 13 show that male/female differences in the frequency of distal radius fractures are statistically significant for comparisons within each race. These tests also indicate that White males and females had a significantly greater frequency of distal radius fractures compared to Black males and females, respectively. Therefore marked sex and race differences characterize the total frequency of distal radius fractures that were encountered in the study. With regard to proximal femur fractures, the chi square values listed in Table 14 show only that White women had a significantly higher frequency of hip fractures compared to all other sex/race subgroups. Given the results presented thus far, the age, sex, and race specific fracture patterns that were found can be described as follows.

TABLE 13
Chi Square Values Comparing Sex and Race Differences in the Total Frequency of Distal Radius Fractures

	White Female	*White Male*	*Black Female*	*Black Male*
White Female	—	13.10[a]	17.84[a]	40.43[a]
White Male		—	0.01	8.07
Black Female			—	6.83[b]
Black Male				—

[a]Significant at the .01 level of probability.
[b]Significant at the .001 level of probability.

Distal Radius Fractures in Hamann-Todd Whites

White males and females displayed dramatic differences in distal radius fracture patterns (see Fig. 5; Tables 7 and 8). In general, fractures were uncommon in White women under 40 years of age. Thereafter, females showed a marked rise in the frequency of fractures. An early peak occurred in the sixth decade. Slightly lower frequencies were seen in the seventh and eighth decades. Nonetheless, the frequency of distal radius fractures remained high in females over 40 years of age, and reached peak incidence in the ninth decade.

TABLE 14
Chi Square Values Comparing Sex and Race Differences in the Total Frequency of Proximal Femur Fractures

	White Female	*White Male*	*Black Female*	*Black Male*
White Female	—	6.70[a]	17.99[b]	15.76[b]
White Male		—	2.77	1.74
Black Female			—	0.14
Black Male				—

[a]Significant at the .01 level of probability.
[b]Significant at the .001 level of probability.

In contrast, White males had a low frequency of distal radius fractures compared to females overall. Men exhibited a minor A-Type fracture pattern during the 20 to 50 year period, and a diminutive J-Type pattern over 60 years of age. The age at onset for increased incidence of distal radius fractures in older men was during the seventh decade. The peak frequency for distal radius fractures in White males occurred in the eighth and ninth decades.

Thus, White men and women showed dramatic differences in age at onset, and frequency of oecurrence, for distal radius fractures. These findings can be summarized as follows. Females displayed an age at onset for increased incidence of distal radius fractures that was 20 years earlier than age at onset for males. Also, women achieved a fracture incidence in the fifth decade that was not attained in males until the eight decade. Finally, females displayed a ninth decade distal radius fraeture incidence that was four times greater than that seen in comparable age-matched males.

Distal Radius Fractures in Hamann-Todd Blacks

In contrast to Whites, the Blacks examined in the study showed lower frequencies of distal radius fractures, and did not display a typical J-Type pattern (see Fig. 5; Tables 9 and 10). The latter finding may be due to the fact that significantly fewer Blacks survived to the later decades of life. However, age and sex specific fracture patterns were seen among the Blacks who were examined. Although Black women under 60 years of age exhibited a slightly higher frequency of distal radius fraetures compared to men, the overall incidence of fractures was low for both sexes during the early and middle years of adulthood. Age at onset for increased frequency of distal radius fractures, as well as age at peak incidence, occurred in the seventh decade for both sexes. The only noteworthy difference between males and females was confined to individuals over 60 years of age. At this time Black women displayed a frequency of distal radius fractures that was 3.5 times greater than that seen in males.

Proximal Femur Fractures in Hamann-Todd Whites

White males and females displayed a typical J-Type pattern for proximal femur fractures (see Fig. 5; Tables 7 and 8). In general, hip fractures were uncommon in men and women that were under 50 years of age. Age at onset for increased incidence of hip fractures was during the sixth decade in females, and the seventh decade in males. Thereafter, the frequency of hip fractures showed a general trend of age progressive increase in both sexes. White men and women in the ninth decade of life showed the highest frequency of hip fractures. Sex differences in

hip fracture incidence were also observed. For all decades over 50 years, White females exhibited frequencies of proximal femur fractures that were at least two times greater than those seen in males. Thus, hip fractures in the Hamann-Todd White sample showed a 10-year sex difference in age at onset, and sex differences in overall frequency of occurrence.

Proximal Femur Fractures in Hamann-Todd Blacks

In contrast to Whites, the Blacks showed a low overall frequency of hip fractures, and did not display a characteristic J-Type pattern (see Fig. 5; Tables 9 and 10). The latter finding is presumed to be, in part, a consequence of poor sampling in the later decades of life, as was the case with distal radius fracture patterns. The age and sex specific patterns for hip fractures that were observed among Blacks are as follows. Hip fractures were uncommon in males and females under 60 years of age. Age at onset for increased incidence of proximal femur fractures was in the seventh decade for men and women. With regard to sex differences, Black females over 60 years of age displayed a frequency of hip fracture that was three times greater than that seen in males. Although age at onset appears to be similar, a sex difference in the frequency of hip fractures among older Blacks is thus suggested.

Evaluation of Age Specific Fracture Patterns

In order to assess the statistical significance of age related differences in the frequency of old-age fractures that were observed, the following procedure was used. Fracture frequency data were compressed into three age groups, which identify early adulthood (18-39 years), middle adulthood (40-59 years), and late adulthood (+60 years). These age intervals also correspond to the premenopausal, climacteric, and postmenopausal years in adult women, respectively. Fracture data that were summarized in this manner are listed in Tables 15 and 16, and illustrated in Fig. 6.

Chi square values for sex specific comparisons of age related differences in the frequency of distal radius fractures are given in Table 17. Results show that (a) White women over 40 years of age had a significantly greater frequency of fractures compared to those women under 40 years of age, (b) White men over 60 years of age had a significantly greater frequency of fractures compared to men that were 40 to 59 years of age, and (c) both Black men and women over 60 years of age had a significantly greater frequency of fractures compared to those individuals that were 18 to 39 years of age. Thus, significant age-related differences in the frequency of distal radius fractures characterize all sex/race subgroups that were examined in the study.

Chi square values listed in Table 18 compare male/female age related differences in the frequency of distal radius fractures that were observed within each race. Results indicate that (a) White females over 40 years of age had a significantly greater frequency of fractures compared to White males, and (b) age related differences in the frequency of distal radius fractures among Black males and females were statistically insignificant.

TABLE 15
White Female and Male Fracture Data Compressed into Age Intervals

		Distal Radius		*Femur (PIC)*		*Femur (PEC)*		*Total Proximal Femur*	
Age	*N*	n_1	%	n_2	%	n_3	%	n_4	%
White Female									
18–39	53	1	1.9	0	0.0	0	0.0	0	0.0
40–59	74	16	21.6	1	1.4	2	2.7	3	4.1
+60	80	23	28.8	3	3.8	14	17.5	17	21.3
Total	207	40	19.3	4	1.9	16	7.7	20	9.7
White Male									
18–39	53	3	5.7	0	0.0	0	0.0	0	0.0
40–59	74	2	2.7	0	0.0	0	0.0	0	0.0
+60	80	10	12.5	2	2.5	5	6.3	7	8.8
Total	207	15	7.2	2	1.0	5	2.4	7	3.4

TABLE 16
Black Female and Male Fracture Data Compressed into Age Intervals

		Distal Radius		*Femur (PIC)*		*Femur (PEC)*		*Total Proximal Femur*	
Age	*N*	n_1	%	n_2	%	n_3	%	n_4	%
Black Female									
18–39	143	4	2.8	0	0.0	0	0.0	0	0.0
40–59	81	6	7.4	0	0.0	0	0.0	0	0.0
+60	38	7	18.4	2	5.3	1	2.6	3	7.9
Total	262	17	6.5	2	0.8	1	0.4	3	1.1
Black Male									
18–39	143	1	0.7	2	1.4	0	0.0	2	1.4
40–59	81	2	2.5	1	1.2	0	0.0	1	1.2
+60	38	2	5.3	1	2.6	0	0.0	1	2.6
Total	262	5	1.9	4	1.5	0	0.0	4	1.5

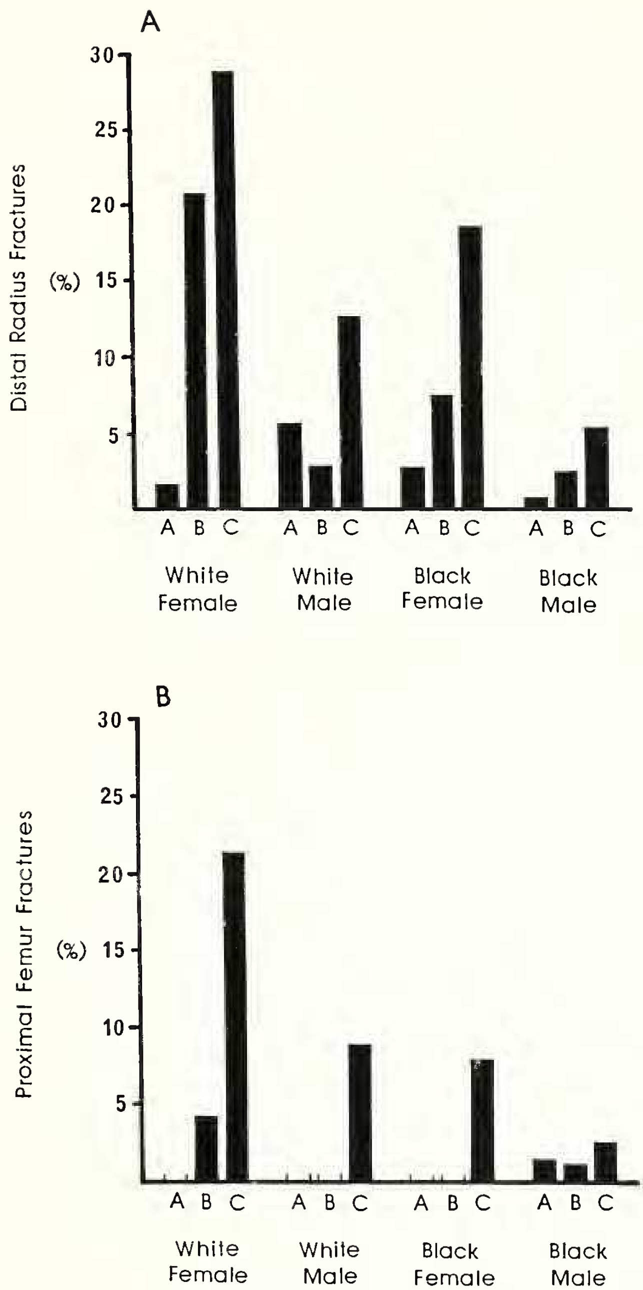


Fig. 6. Frequency of distal radius and proximal femur fractures partitioned by sex and race for the age groups A (18-39), B (40-59), and C (+60 years).

Finally, chi square values given in Table 19 compare male/male and female/female age related differences in the frequency of distal radius fractures between each race. Results show that (a) White females over 40 years of age had a significantly higher frequency of fractures compared to Black females, and (b) young adult White males had a significantly higher frequency of fractures compared to young adult Black males. No other race differences in the age specific frequency of distal radius fractures were statistically significant.

TABLE 17
Chi Square Values for Distal Radius Fracture Age Group Comparisons Partitioned by Sex and Race

Age Group Comparison	*White Female*	*White Male*	*Black Female*	*Black Male*
18–39 vs. 40–59	9.18[a]	0.71	2.58	1.22
18–39 vs. +60	14.25[b]	1.69	12.84[b]	4.25[c]
40–59 vs. +60	1.03	5.14[c]	3.22	0.78

[a]Significant at the .01 level of probability.
[b]Signifieant at the .001 level of probability.
[c]Significant at the .05 level of probability.

TABLE 18
Chi Square Values for Distal Radius Fracture Age Group Comparisons between the Sexes and Partitioned by Race

Age	*White Male vs. Female*	*Black Male vs. Female*
18–39	0.84	1.53
40–59	11.26[a]	1.52
+60	6.45[b]	2.44

[a]Significant at the .001 level of probability.
[b]Significant at the .05 level of probability.

TABLE 19
Chi Square Values for Distal Radius Fracture Age Group Comparisons between the Races and Partitioned by Sex

Age	*Male Black vs. White*	*Female Black vs. White*
18–39	4.80[a]	0.01
40–59	0.01	6.42[a]
+60	0.95	1.45

[a]Significant at the .05 level of probability.

Statistical analyses similar to those presented above were not conducted for proximal femur fractures. This is because hip fractures were infrequent overall, and they were particularly rare in those individuals that were under 60 years of age at time of death. Nonetheless, the age related patterns in Fig. 5 clearly demonstrate that hip fractures were of no epidemiological significance in either Blacks or Whites prior to the onset of old age.

Discussion

With regard to the replicative goals of this study, a number of statements can be made concerning the age,

sex, and race specific fracture patterns that were predicted earlier. Hypotheses 1, 2, 3, 6, and 7 were confirmed as stated. Hypotheses 4, 5, and 9 were confirmed with minor qualifications. Only hypothesis number 8 was found to be incorrect. For each hypothesis given, the fracture patterns that were observed can be summarized as follows.

(1) White females displayed a significantly greater frequency of distal radius fractures compared to all other sex/race subgroups.
(2) Age at onset for increased incidence of distal radius fractures in White women occurred in the 40 to 60 age group.
(3) White females displayed a significantly greater frequency of hip fractures compared to all other sex/race subgroups.
(4) Age at onset for increased incidence of hip fractures in White women occurred during the sixth decade of life (i.e., 10 years earlier than predicted.
(5) Age at onset for increased incidence of hip fractures in White men occurred during the seventh decade (i.e., 10 years earlier than predicted. Age at onset in males did occur approximately 10 years later than in females.
(6) A low frequency of hip fractures characterized all sex/race subgroups that were under 60 years of age at time of death.
(7) Black men and women showed a lower frequency of distal radius and proximal femur fractures at all ages compared to White men and women, respectively. The only exception to this pattern was that Black females had a slightly higher incidence of distal radius fractures in the fourth and seventh decades compared to White females. However, these minor differences were insignificant, and not apparent in smoothed comparisons of age grouped data.
(8) Contrary to the pattern predicted earlier, Black men and women that were over 60 years of age did display a significantly greater frequency of distal radius fractures compared to Black men and women in the 18 to 39 age group.
(9) Black males displayed the lowest frequency of distal radius and proximal femur fractures compared to all other sex/race subgroups. The only exception to this was that Black men showed a slightly greater, but insignificant, total frequency of hip fractures compared to Black women. However, data summarized earlier indicate that several hip fractures in Black males occurred in individuals that were under 60 years of age at time of death. As predicted, Black women over 60 years showed a higher age specific frequency of hip fractures compared to Black men.

Therefore, it is quite clear that the age, sex, and race specific patterns that characterize distal radius and proximal femur fractures among Hamann-Todd Blacks and Whites strongly conform to fracture patterns that have been reported for more recent American and European urban industrial populations. However, one interesting observation concerns the finding that Hamann-Todd Black and White men both displayed an increased frequency of distal radius fractures in individuals over 60 years of age. Fracture epidemiology studies, which were conducted during the mid 1950's, report that older males showed no increased incidence of distal radius fractures with age (Buhr and Cooke 1959; Bauer 1960). Nonetheless, more recent surveys document a secular trend whereby men, and women, display marked increases in the incidence of both distal radius and hip fractures in individuals over 60 years of age (Nilsson and Obrant 1978; Zetterberg and Andersson 1982; Frandsen and Kruse 1983; Swanson and Murdoch 1983; Wallace 1983; Zain et al. 1984; Bengner and Johnell 1985; Solgaard and Petersen 1985). Thus, the increased frequency of distal radius fractures that was seen in older Hamann-Todd Collection Black and White men should not be regarded as an unexpected, or unusual, finding.

The most striking difference found in this investigation concerns the remarkable frequency with which distal radius and proximal femur fractures occurred in Hamann-Todd individuals. In order to emphasize this point, the Hamann-Todd fracture data were converted to total incidence per 10,000. This information is summarized in Table 20. Also given is the total incidence per 10,000 for distal radius and hip fractures as computed for data reported for the population in Malmo, Sweden in 1955 (Bauer 1960).

Fracture ratios for the distal radius indicate that

TABLE 20
Total Incidence of Old Age Fractures

Subgroup	*Distal Radius Fractures* *H-T*[a]	*M-S*[b]	*Ratio*	*Proximal Femur Fractures* *H-T*	*M-S*	*Ratio*
White Female	1932	116	16.7	966	93	10.4
White Male	725	22	33.0	338	30	11.3
Black Female	649	116	5.6	115	93	1.2
Black Male	191	22	8.7	153	30	5.1

[a]Total incidence per 10,000 for the Hamann-Todd study sample of early twentieth century American Blacks and Whites.
[b]Total incidence per 10,000 for distal radius and proximal femur fractures reported for European White males and females in Malmo, Sweden in 1955 (Bauer 1960).

Hamann-Todd total fracture incidence is (a) 17 times greater for White women, (b) 33 times greater for White men, (e) 6 times greater for Black women, and (d) 9 times greater for Black men compared to the modern group. Although less marked, fracture ratios for hip trauma show that Hamann-Todd total fracture incidence is (a) 10 times greater for White females, (b) 11 times greater for White males, (c) nearly identical for Black females and (d) 5 times greater for Black males. Given the known biased composition of the Hamann-Todd Collection, and lacking any other fracture data from the earlier part of the 20th century in urban America, it is suggested here that Hamann-Todd individuals represented a cross section of society at very high risk of traumatic injury.

The final issue to be addressed here concerns the etiology of distal radius fractures in Caucasian women. All fracture epidemiology studies that have been conducted thusfar (i.e., those cited herein) are in agreement with the following perspectives. First, the majority of distal radius fractures that occur in all age/sex/race groups are the simple eonsequence of accidental falls from level ground. Second, the age at onset for a marked increase in the incidence of distal radius fractures in White females is strongly associated with the climateric years of life. Third, studies have shown that bone loss with age is most pronounced in Caucasian women compared to all other age-matched sex and race groups. Fourth, skeletal fragility is regarded as the primary risk factor responsible for the early onset, and high incidence, of distal radius fractures in Caucasian females.

Although senile and postmenopausal osteoporosis are clearly implicated in the pathogenesis of hip fractures in men and women that are over 60 years of age, we consider it improbable that bone loss alone could account for the early onset, high frequency, and marked differences that have been observed for distal radius fracture patterns in Caucasian women compared to men. Indeed, do perimenopausal and menopausal females 'fall' more frequently than their premenopausal peers? If so, it would be of interest to know whether or not such falls were merely routine accidents, or whether such episodes were initiated by physiologieal disturbances common to this particular age and sex group.

Thus, it is suggested here that physiological consequenees of estrogen withdrawal other than bone loss may be important factors, which play a role in promoting accidents and elevating fracture risk during the climacteric years of life in women. The latter is defined as the period encompassing the onset of menstrual irregularity, overt menopause, and several years following the complete cessation of menses. That is, the period from 45 to 60 years, with the median age of menopause occurring at approximately 50 years (Frommer 1964; Dennerstein and Burrows 1978).

It is important for fracture epidemiologists to realize that over the last decade clinical researchers have devoted greater attention to the psychological, behavioral, biochemical, and physiological changes that occur in women undergoing the menopausal transition (McKinley and Jefferys 1974; Dennerstein and Burrows 1978; Casper et al. 1979; Tataryn et al. 1980). The problems encountered by these individuals include an increased incidence of psychosomatic illness, vaginal atrophy osteoporosis and vasomotor disturbances (Voda 1981). However, the latter are by far the most frequent symptoms (e.g., hot flushes, night sweats, etc), which generate discomfort and anxiety. Indeed, studies show that 75% of women undergoing natural menopause experience a variable frequency, intensity, and duration of vasomotor disturbances during the climacteric period. (McKinley and Jefferys 1974; Voda 1981; Felman et al 1985).

One of the most informative studies of the menopausal syndrome in Caucasian women was conducted by Bungay and colleagues (1980). They found that (a) symptoms of vasomotor disturbanee were strongly associated with the climacteric period, and (b) peak frequency of symptoms closely corresponded to the median age of menopause. The vasomotor disturbances displaying this marked age and sex specific pattern were classified as Type 3a responses (see Bungay et al. 1980). The latter include hot flushes, night sweats, day sweats, dizzy spells, tiredness, palpitations, difficulty in eoncentration, difficulty in making decisions, loss of eonfidence, forgetfulness, and feelings of unworthiness. Unfortunately, similar information about the menopausal experience in Black women is unavailable.

The age specific pattern for the frequency of vasomotor disturbances as seen in modern White climacteric women (Bungay et al. 1980) is illustrated in Fig. 7. Also shown is the age specific frequency with which distal radius fractures were observed in Hamann-Todd White females. The vasomotor disturbance data exhibits a typical A-Type pattern. It can be seen that the age related pattern for distal radius fractures in Hamann-Todd Caucasian women parallels the frequency of vasomotor disturbances for those individuals that ranged in age from 40 to 65 years.

Although falls from level ground are recognized as the major circumstance in which distal radius fractures occur, it is perhaps worthy of comment that no studies have ever reported the results of inquires as to why patients fell in the first place. That is, we have no direct knowledge of the extent to which dizzy spells or other vasomotor disturbances may have preceeded, or initiated, accidental falls. Thus, the data illustrated in Fig. 7 prompt us to suggest that vasomotor disturbances may play a significant role in initiating a greater frequency of accidents and, subsequently, an early onset and elevated incidence of distal radius fractures in climacteric White females.

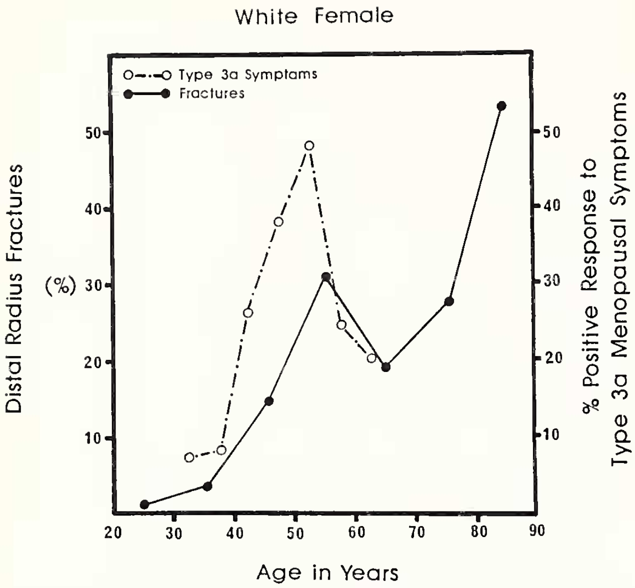
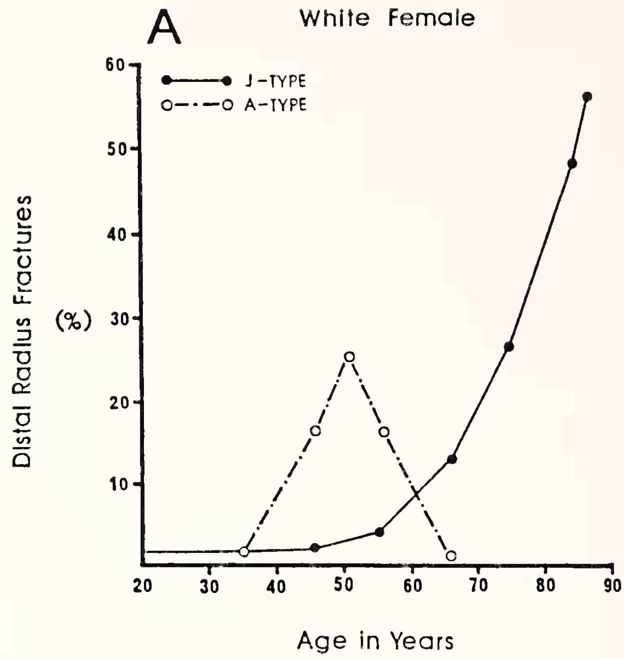


Fig. 7. Frequency of distal radius fractures in Hamann-Todd White females, compared to the age specific frequency of Type 3a menopausal symptoms reported for modern White females (see Bungay et al., 1980). Type 3a responses are a class of symptoms due to vasomotor disturbances that accompany estrogen withdrawal in women during the climacteric years of life.



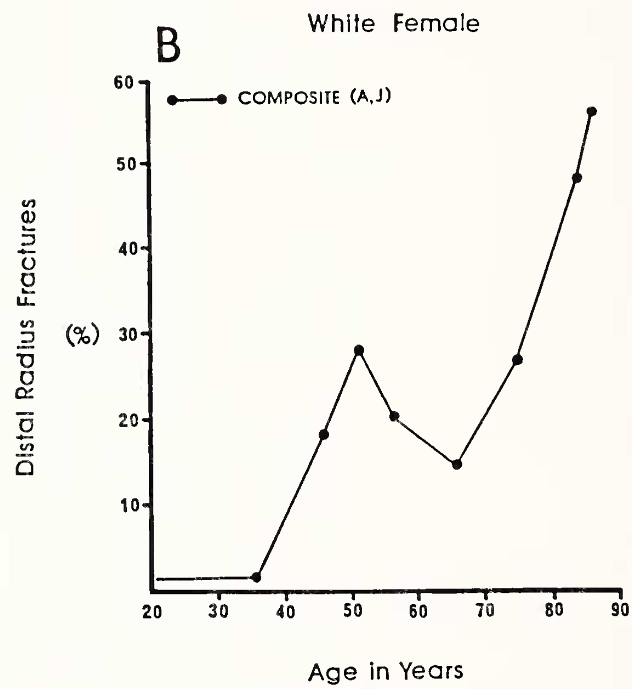


Fig. 8. Hypothetical age specific distal radius fracture pattern for Caucasian women. The proposed A-Type pattern during the climacteric years, and the J-Type pattern for postmenopausal females are illustrated separately in Fig. 8A. The cumulative frequency of distal radius fractures which would be observed for the A/J-Composite pattern is shown in Fig. 8B.

Based on the age and sex specific physiological relationships described thus far, it is further suggested that distal radius fractures in adult White women may be characterized by an overlapping A/J-Composite fracture profile. The A and J-Type components that correspond to the hypothetical fracture pattern are illustrated in Fig. 8A. The additive distal radius fracture incidence which would result from such a pattern is shown in Fig. 8B. It is hypothesized that the A-Type distal radius fracture component should bracket the climacteric period. During this time, vasomotor disturbances would be regarded as the dominant, but not sole, factor in fracture etiology. Therefore, the age at onset, peak incidence, and age at decline for distal radius fractures should parallel changing frequencies of vasomotor disturbances.

The second, J-Type distal radius fracture component would be regarded as a primary consequence of age progressive bone loss and other degenerative sequelae discussed earlier. Thus, as vasomotor disturbances decrease in frequency at the end of the climacteric period, it would be expected that skeletal fragility will play a dominant role in the increased incidence of distal radius fractures, as is the circumstance with hip trauma among older men and women alike.

The striking similarity between the hypothetical composite White female distal radius fracture pattern, and the pattern that was observed for Hamann-Todd White females, has not escaped our attention. However, several problems which limit our basis of inference deserve comment here. The hypothetical composite fracture pattern would receive support from our findings if the majority of distal radius fractures that were seen in Hamann-Todd individuals had occurred with five years of age at death. This circumstance is considered to be unlikely. Most of these traumatic injuries were, to some

degree, remodeled at time of death and true age at occurrence remains unknown. Therefore, the age specific frequencies that were reported for Hamann-Todd distal radius fractures are best regarded as cumulative data. Furthermore, the high 6th decade incidence of distal radius fractures that was seen in Hamann-Todd White females, relative to 7th and 8th decade values, can just as readily be interpreted as a consequence of sampling errors.

More recent epidemiological studies do not permit evaluation of the hypothetical White female composite distal radius fracture pattern for other reasons. The most important among these is the effective clinical management of bone loss. Over the past two decades, prophylactic and therapeutic use of hormonal and nutritional supplements has become increasingly widespread as a means to slow bone loss in aging Caucasian women (Gordon 1961; Nicholas and Wilson 1963; Davis et al. 1966; Lafferty et al. 1969; Riggs et al. 1976; Gallagher and Riggs 1978). Numerous clinical studies document that accelerated rates of bone loss can be retarded if estrogen replacement therapy is begun within the first few years of natural, or surgical, menopause (Meema et al. 1975; Meema and Meema 1976; Aitken et al. 1976; Nordin et al. 1976; Horsman et al. 1977).

With regard to fracture patterns, it is important to realize that widespread use of estrogen replacement therapy in climacteric women also has the effect of reducing the frequency, intensity, and duration of vasomotor disturbances that would otherwise occur in these individuals (Bungay et al. 1980; Hammar et al. 1984). Thus, it is reasonable to expect that the hypothesized A-Type climacteric distal radius fracture component in modern White females will be reduced in magnitude and shifted upward in age. The A- and J-Type fracture patterns would then show significant overlap. The resultant modern fracture profile might then give the appearance of an early onset J-Type pattern that attains a plateau phase, or simply an age progressive J-Type pattern. The most recent distal radius fracture patterns, which have been reported for Caucasian women, are in accord with the expectations posited above (see Solgaard and Petersen 1985; and Bengner and Johnell 1985).

The retrospective analysis presented here, and more contemporary research described above, do not allow us to assess the validity of the hypothetical A/J-Composite distal radius fracture pattern as posited for Caucasian women. Nonetheless, it is interesting that Hamann-Todd White females display an age specific distal radius fracture pattern similar to the one we would predict to occur in a population that did not experience the benefits of estrogen replacement therapy and recommended nutritional supplementation. Therefore, resolution of the vasomotor disturbance hypothesis, as well as information about fracture patterns and other aspects of aging in modern Black men and women, deserve attention in future gerontological research.

Summary and Conclusion

The study presents a retrospective analysis of distal radius and proximal femur fractures that occurred in 938 Hamann-Todd Collection skeletons. The Black and White individuals included in the investigation were retrieved from dissecting room cadavers in Cleveland, Ohio, between the years 1910 and 1938. Thus, the sample represents a biased cross section of an early twentieth century American urban industrial society.

Demographic analysis demonstrated that the mean age at death for Blacks, 41.9 years, was significantly lower than the mean age at death for Whites, 53.8 years, for those individuals examined. Therefore, the small proportion of Blacks over 60 years of age that were represented was considered a potential source of sampling error, with respect to our ability to accurately estimate the frequency of old age fractures in this group.

Fracture symmetry data indicate that 8-9% of all distal radius and hip fractures occurred bilaterally. However, it was not possible to determine if bilateral involvements were the result of one or more traumatic injuries. It is probable that several of these occurred at different times during the life of affected individuals. Unilateral involvements showed no side preference for any of the fracture types that were examined.

With regard to fracture repair status, it was found that 88% of distal radius fractures, and 87% of intracapsular hip fractures, displayed moderate to marked bone remodeling at time of death. It was concluded that these fractures were well tolerated from a clinical perspective. In contrast, only 23% of extracapsular hip fractures were remodeled at time of death. It was therefore concluded that Hamann-Todd individuals with these traumatic injuries were at a significantly high risk of mortality.

The age, sex, and race specific fracture patterns, which characterize the Hamann-Todd sample, were found to correspond strongly to those seen in modern European and American communities. Therefore, the replicative goals of the study were confirmed with few exceptions. Results are summarized as follows.

(1) White women displayed a significantly greater frequency of distal radius fractures compared to all other sex/race subgroups.
(2) Age at onset for increased incidence of distal radius fractures in White females occurred during the 40 to 60 year period.
(3) Caucasian women displayed a significantly greater frequency of hip fractures compared to all other sex/race subgroups.
(4) A low frequency of hip fractures characterized all sex/race subgroups that were under 60 years of age at time of death.
(5) Age at onset for increased incidence of hip fractures in White females occurred during the

6th decade, and peak frequency of hip trauma was seen in the ninth decade.

(6) Age at onset for increased incidence of hip fractures in White males occurred during the seventh decade, 10 years later than females, and peak frequency of hip trauma was observed in the ninth decade.

(7) Black men and women showed a low frequency of distal radius and proximal femur fractures at all ages compared to White men and women, respectively.

(8) Black men and women that were over 60 years of age showed a significantly greater frequency of distal radius fractures compared to those Blacks in the 18 to 39 year age group.

(9) Black males exhibited the lowest frequency of distal radius and proximal femur fractures compared to all other sex/race subgroups. The only exception to this was that Black females had a slightly lower total number of hip fractures compared to males.

The most dramatic difference between fracture patterns reported in modern groups and those which were observed for the Hamann-Todd sample concerns the much greater total frequency with which distal radius and proximal femur fractures occurred in the latter group. Distal radius fracture ratios indicate that the total frequency of traumatic injury for Hamann-Todd was (a) 17 times greater in White women, (b) 33 times greater in White men, (c) 6 times greater in Black women, and (d) 9 times greater in Black men, compared to a modern group.

Similarly, hip fracture ratios show that the total frequency of these traumatic injuries for Hamann-Todd was (a) 10 times greater in White females, (b) 11 times greater in White males, (c) nearly identical in Black females, and (d) 5 times greater in Black males, compared to a modern group. These findings support the conclusion that individuals in the Hamann-Todd Collection represent a cross section of early twentieth century urban industrial society that was at very high risk of traumatic injury.

Although hip fracture patterns appear to be a primary consequence of age progressive skeletal fragility, it is suggested that bone loss alone may not explain the early onset and high incidence of distal radius fractures that are known to characterize middle-aged Caucasian women. Alternatively, it is posited that vasomotor disturbances, which accompany estrogen withdrawal in climacteric women, may play a more important role in initiating a greater frequency of accidental falls. The latter would result in elevated distal radius fracture rates in climacteric White females, prior to significant reduction of skeletal mass and biomechanical strength.

Finally, it is further suggested that adult Caucasian women in pre-estrogen replacement therapy societies may be characterized by a A/J-Composite distal radius fracture pattern. Here, vasomotor disturbances would dominate fracture risk in the climacteric years, and skeletal fragility would dominate fracture risk in individuals over 60 years of age. With respect to Black men and women, we regard the lack of comparative information about fracture patterns, aging effects in general, and the menopausal syndrome in Black women in particular, to constitute gerontological issues that deserve attention in future research.

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Appendix A

CSU-OAFS (Cleveland State University—Old Age Fracture Study) List of All Fractured Individuals

Code:

a) *H-T No.*, Hamann-Todd Catalogue Number.
b) *Age*, Cadaver Record Stated Age at Death.
c) *Distal Radius*, all fractures that were located within 4 cm. of the distal articular surface of the radius.
d) *Femur (PIC)*, Intracapsular Proximal Femur Fractures.
e) *Femur (PEC)*, Extracapsular Proximal Femur Fractures.
f) *R*, Right Side Affected.
g) *L*, Left Side Affected.
h) *r*, all fractures which were remodeled, or evinced only minimal and initial remodeling, at time of death.

CSU-OAF STUDY

Adult White Female Fracture Specimens

H-T No.	*Age*	*Distal Radius*	*Femur Head*	*Femur Neck*
2478	35	R-r/L-r		
0228	40	R-r		
0415	40	R-r		
0783	42	R-u		
1119	45	R-r		
2437	45	R-r		
2414	47	R-r/L-r		
0355	49			L-u
0229	50	L-r		
0411	50			L-u
0742	50	R-r		
1149	50	R-r		
3123	51	L-r		
1846	53	R-r		
3140	53	L-r		
0785	54	L-r		
3118	54	L-r		
3352	54	L-u		
2949	58		L-u/R-u	
3327	58	R-r		
0022	60	R-r/L-r		L-u
0541	60	R-u		
1426	60	L-r		
3132	61	R-r		R-r
3164	62	L-r		
0234	65			R-u
1200	68			L-U
2307	68	R-r		R-r
1413	72	R-r		
1811	73	L-r		
3151	74	R-u		
1451	75			L-r
1750	75	R-r		
2188	75	R-r		
2021	76			R-u
3183	77	L-r		
3278	77			L-u
1191	78	L-r		
1779	78	L-r		
3359	78	L-r		L-u
0927	80	L-r		
1680	80	R-r		
1753	80		R-r	
1754	80			L-u
1402	81	L-r/R-r	R-r	
1505	81	L-r		L-r
2007	81			R-r
1581	83	L-r/R-r		
1024	84		R-r/L-r	
1433	84	R-r		
2121	85	L-r		
3032	89	R-r		L-u
1708	93			R-u

Adult White Male Fracture Specimens

2689	38	L-r		
2580	40	R-r		
1765	40	L-r		
2618	48	L-u		
2198	58	R-r		
1064	60	L-r		
1464	60	L-u		
0963	65			R-u
2626	65		R-r	
3147	69	L-r		
0759	73	L-r		
3341	75			L-u
1989	75	L-u		
1166	76	L-r		
2801	78	R-r		
3081	78	R-r		
1021	81	L-r		
1307	83			R-u
2635	84		R-r	
1663	85	R-r		
3214	89			L-u
3025	93			R-u

Adult Black Female Fracture Specimens

0918	35	R-u		
2311	35	R-r		
2612	39	R-r		
2942	39	L-r		
1702	40	R-r		
3131	43	L-r		

H-T No.	*Age*	*Distal Radius*	*Femur Head*	*Femur Neck*
1022	46	R-r		
3182	48	L-r		
2660	51	R-r		
2269	58	R-u/L-u		
0839	60	R-r		
0773	60			R-u
1551	60		L-r	
1912	60	L-r		
3174	60	L-r		
2773	64	L-r		
0751	65	R-r		
2039	65	L-r		
1367	72		L-r	
0967	87	R-r		
Adult Black Male Fracture Specimens				
0598	25	R-r		
2368	26		L-r/R-r	
1245	31		L-r	
1291	42		L-r	
1338	42	R-r		
2339	52	L-r		
1452	60	R-r		
1733	60		R-r	
1528	67	R-r/L-r		

TABLE 21
Summary of Fracture Observations

	White Female	*White Male*	*Black Female*	*Black Male*	*Total*
Distal Radius Fx	45	15	18	6	84
Remodeled	41	12	15	6	74
Unremodeled	4	3	3	0	10
Unilateral Left	16	10	9	1	36
Unilateral Right	19	5	7	3	34
Bilateral	5	0	1	1	7
Femur (PIC) Fx	6	2	2	5	15
Remodeled	4	2	2	5	13
Unremodeled	2	0	0	0	2
Unilateral Left	0	0	2	2	4
Unilateral Right	2	2	0	1	5
Bilateral	2	0	0	1	3
Femur (PEC) Fx	16	5	1	0	22
Remodeled	5	0	0	0	5
Unremodeled	11	5	1	0	17
Unilateral Left	10	2	0	0	12
Unilateral Right	6	3	1	0	10
Bilateral	0	0	0	0	0
TNIFx[a]	53	22	20	9	104
TNFx[b]	67	22	21	11	121

[a]Total no. of individuals that displayed one or more OAF fractures.
[b]Total no. of OAF fractures observed in each subsample.

Appendix B

TABLE 22
Distal Radius and Proximal Femur Fracture
Symmetry Data

	Individuals with Fractures N	*Left n_1*	*%*	*Right n_2*	*%*	*Bilateral n_3*	*%*
DISTAL RADIUS							
White Female	40	16	40.0	19	47.5	5	12.5
White Male	15	10	66.7	5	33.3	0	0.0
Black Female	17	9	52.9	7	41.2	1	5.9
Black Male	5	1	20.0	3	60.0	1	20.0
Total	77	36	46.8	32	41.6	7	9.1
FEMUR (PIC)							
White Female	4	0	0.0	2	50.0	2	50.0
White Male	2	0	0.0	2	100.0	0	0.0
Black Female	2	2	100.0	0	0.0	0	0.0
Black Male	4	2	50.0	1	25.0	1	25.0
Total	12	4	33.3	5	41.7	3	25.0
FEMUR (PEC)							
White Female	16	10	62.5	6	37.5	0	0.0
White Male	5	2	40.0	3	60.0	0	0.0
Black Female	1	0	0.0	1	100.0	0	0.0
Black Male	0	0	0.0	0	0.0	0	0.0
Total	22	12	54.5	10	45.5	0	0.0

Appendix C

TABLE 23
Distal Radius and Proximal Femur Fracture
Remodeling Status

	Total Fractures Observed	*Remodeled n_1*	*%*	*Unremodeled n_2*	*%*
DISTAL RADIUS					
White Female	45	41	91.1	4	8.9
White Male	15	12	80.0	3	20.0
Black Female	18	15	83.3	3	16.7
Black Male	6	6	100.0	0	0.0
Total	84	74	88.1	10	11.9
FEMUR (PIC)					
White Female	6	4	66.7	2	33.3
White Male	2	2	100.0	0	0.0
Black Female	2	2	100.0	0	0.0
Black Male	5	5	100.0	2	13.3
Total	15	13	86.7	2	13.3
FEMUR (PEC)					
White Female	16	5	31.3	11	68.8
White Male	5	0	0.0	5	100.0
Black Female	1	0	0.0	1	100.0
Black Male	0	0	22.7	17	77.3
Total	22	5	22.7	17	77.3

Appendix D

TABLE 24
White Female Age Specific Fracture Frequencies

Age Group	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–24	5	0	0.0	0	0.0	0	0.0	0	0.0
25–29	14	0	0.0	0	0.0	0	0.0	0	0.0
30–34	10	0	0.0	0	0.0	0	0.0	0	0.0
35–39	24	1	4.2	0	0.0	0	0.0	0	0.0
40–44	19	3	15.8	0	0.0	0	0.0	0	0.0
45–49	22	3	13.6	0	0.0	1	4.5	1	4.5
50–54	24	9	37.5	0	0.0	1	4.2	1	4.2
55–59	9	1	11.1	1	11.1	0	0.0	1	11.1
60–64	19	5	26.3	0	0.0	2	10.5	2	10.5
65–69	13	1	7.7	0	0.0	3	23.1	3	23.1
70–74	13	3	23.1	0	0.0	0	0.0	0	0.0
75–79	20	6	30.0	0	0.0	4	20.0	4	20.0
+80	15	8	53.3	3	20.0	5	33.3	8	53.3
Total	207	40	19.3	4	1.9	16	7.7	20	9.7

TABLE 25
White Male Age Specific Fracture Frequencies

Age Group	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–24	5	0	0.0	0	0.0	0	0.0	0	0.0
25–29	14	0	0.0	0	0.0	0	0.0	0	0.0
30–34	10	0	0.0	0	0.0	0	0.0	0	0.0
35–39	24	1	4.2	0	0.0	0	0.0	0	0.0
40–44	19	2	10.5	0	0.0	0	0.0	0	0.0
45–49	22	1	4.5	0	0.0	0	0.0	0	0.0
50–54	24	0	0.0	0	0.0	0	0.0	0	0.0
55–59	9	1	11.1	0	0.0	0	0.0	0	0.0
60–64	19	2	10.5	0	0.0	0	0.0	0	0.0
65–69	13	1	7.7	1	7.7	1	7.7	2	15.4
70–74	13	1	7.7	0	0.0	0	0.0	0	0.0
75–79	20	4	20.0	0	0.0	1	5.0	1	5.0
+80	15	2	13.3	1	6.7	3	20.0	4	26.7
Total	207	15	7.2	2	1.0	5	2.4	7	3.4

TABLE 26
Blaek Female Age Specific Fracture Frequencies

Age Group	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–24	30	0	0.0	0	0.0	0	0.0	0	0.0
25–29	34	0	0.0	0	0.0	0	0.0	0	0.0
30–34	29	0	0.0	0	0.0	0	0.0	0	0.0
35–39	50	4	8.0	0	0.0	0	0.0	0	0.0
40–44	29	2	6.9	0	0.0	0	0.0	0	0.0
45–49	21	2	9.5	0	0.0	0	0.0	0	0.0
50–54	23	1	4.4	0	0.0	0	0.0	0	0.0
55–59	8	1	12.5	0	0.0	0	0.0	0	0.0
60–64	10	4	40.0	1	10.0	1	10.0	2	20.0
65–69	10	2	20.0	0	0.0	0	0.0	0	0.0
70–74	10	0	0.0	1	10.0	0	0.0	1	10.0
75–79	2	0	0.0	0	0.0	0	0.0	0	0.0
+80	6	1	16.7	0	0.0	0	0.0	0	0.0
Total	262	17	6.5	2	0.8	1	0.4	3	1.1

TABLE 27
Black Male Age Specific Fracture Frequencies

Age Group	N	Distal Radius n_1	%	Femur (PIC) n_2	%	Femur (PEC) n_3	%	Total Proximal Femur n_4	%
18–24	30	0	0.0	0	0.0	0	0.0	0	0.0
25–29	34	1	2.9	1	2.9	0	0.0	1	2.9
30–34	29	0	0.0	1	3.4	0	0.0	1	3.4
35–39	50	0	0.0	0	0.0	0	0.0	0	0.0
40–44	29	1	3.4	1	3.4	0	0.0	1	3.4
45–49	21	0	0.0	0	0.0	0	0.0	0	0.0
50–54	23	1	4.3	0	0.0	0	0.0	0	0.0
55–59	8	0	0.0	0	0.0	0	0.0	0	0.0
60–64	10	1	10.0	1	10.0	0	0.0	1	10.0
65–69	10	1	10.0	0	0.0	0	0.0	0	0.0
70–74	10	0	0.0	0	0.0	0	0.0	0	0.0
75–79	2	0	0.0	0	0.0	0	0.0	0	0.0
+80	6	0	0.0	0	0.0	0	0.0	0	0.0
Total	262	5	1.9	4	1.5	0	0.0	4	1.5